A experimental European multi-site deep-space optical study

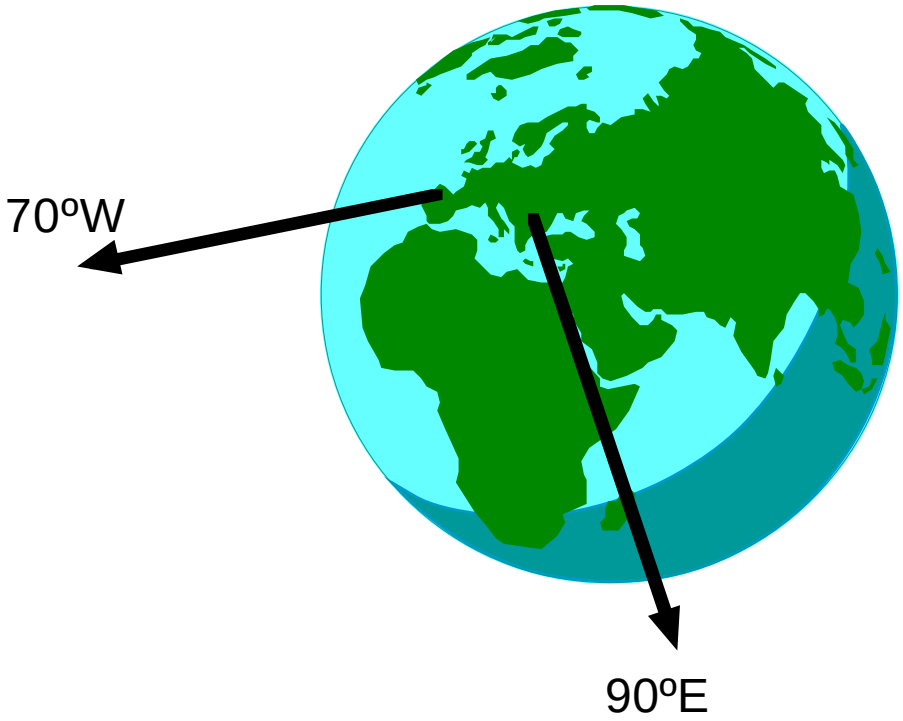
Dick, J., Herridge, P.
Observatory Sciences Ltd., United Kingdom

Schildknecht, T., Ploner, M.,
Astronomical Institute, University of Bern, Switzerland

Bain, M., Holland, D.,
Ministry of Defence, United Kingdom

Thinking about deep-space surveillance. . .

Coverage, sensor type, & catalogue maintenance



Radar: No weather problems
Good **r** and d**r**/dt
Possible imaging information
but
Expensive
r^-4 sensitivity law
Small field of view in deep-space

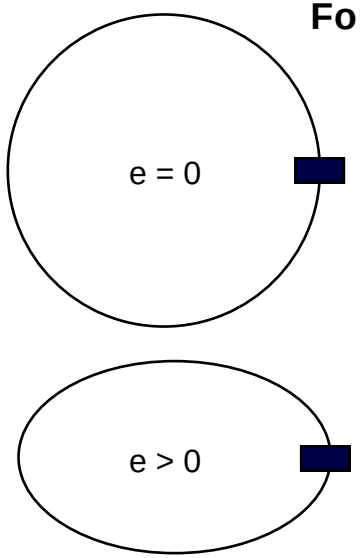
Optics: Weather problems
Poor orbits from short-arcs
but
Not expensive
r^-2 sensitivity law
Large field of view in deep-space

Catalogue maintenance:

Good detection & large volume
Good orbits

The optics and orbits problem . . .

For short-arc observations (typical of surveillance/ debris searches)



Semi-major axis (*a*) ✔

Plane of orbit (*i*, Ω) ✔

Ellipticity (*e*, ω) Not applicable

Semi-major axis (*a*) ?

Plane of orbit (*i*, Ω) ~ ✔

Ellipticity (*e*, ω) ✖

“No shows” during follow-up searches

Objects “discovered” more than once

Poor catalogue

The optics and orbits problem . . .

How to be misled: ***try to fit a circular orbit***

Along-track error ~ $(\nu - M)^o \sim 2\ e \sin(M) + \ldots \sim$ +/– 300 δe ^{o} at worst

Orbit plane (i, Ω) error ~ some^o

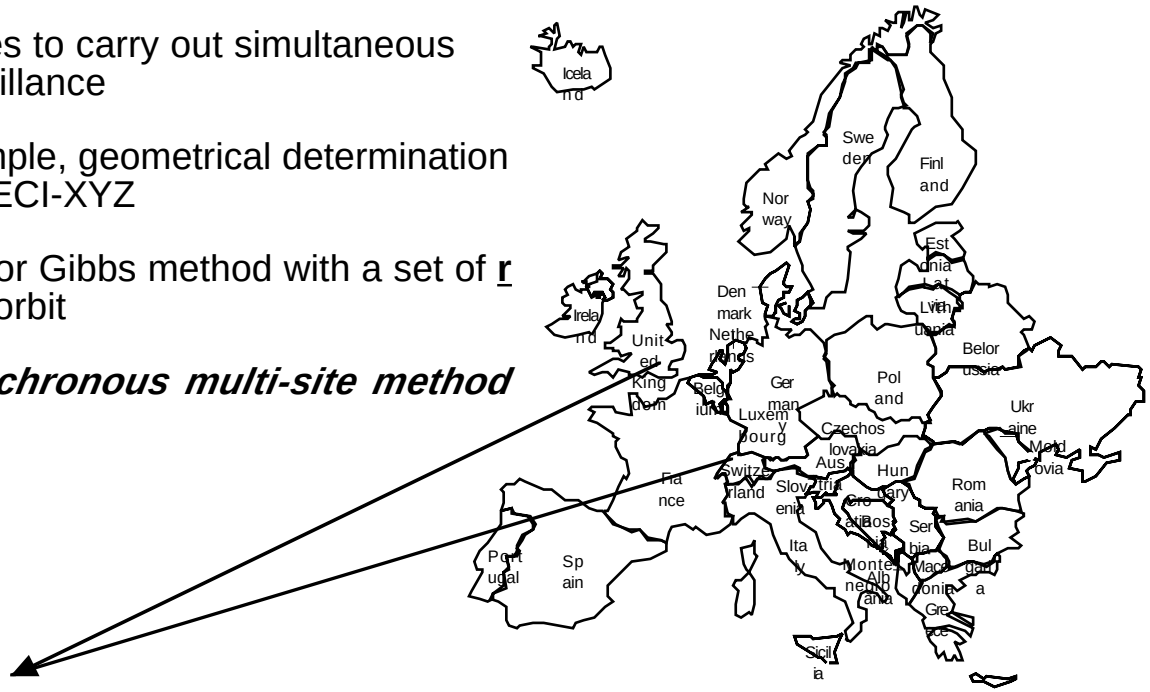
Semi-major axis (a) error ~ many^o/day

The optics and orbits problem . . .

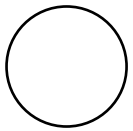
How to <u>avoid</u> being misled, part 1

- Use *two* sites to carry out simultaneous volume surveillance
- Obtain a simple, geometrical determination of object **<u>r</u>** in ECI-XYZ
- Use Gauss or Gibbs method with a set of **<u>r</u>** to determine orbit

. . . the synchronous multi-site method

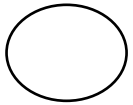


Modelling the method and assessing potential . . .



***e* ~ 0** **Typical GEO payload**

Circular orbit generally best; synchronous multi-site (SMS) track gives small, spurious eccentricity which is not a problem to detect.



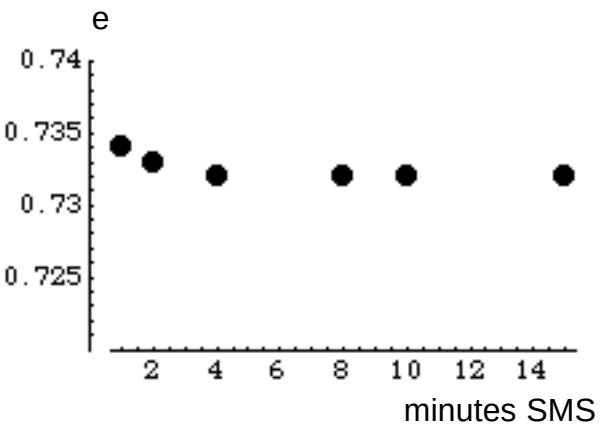
***e* ~ 0.01 GEO debris** **TEST CASE**

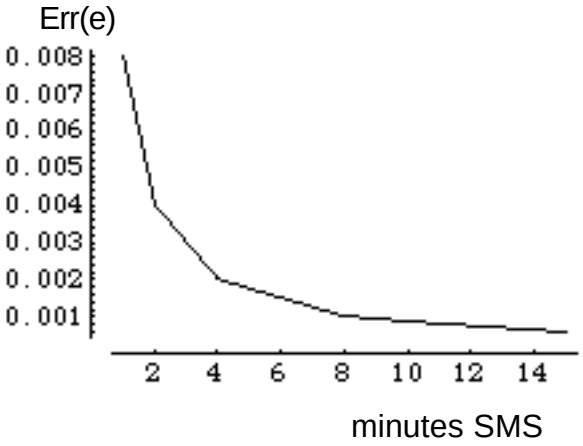
***e* ~ 0.73** **Typical GTO**

4 to 8 minutes SMS track gives excellent re-acquisition expectations

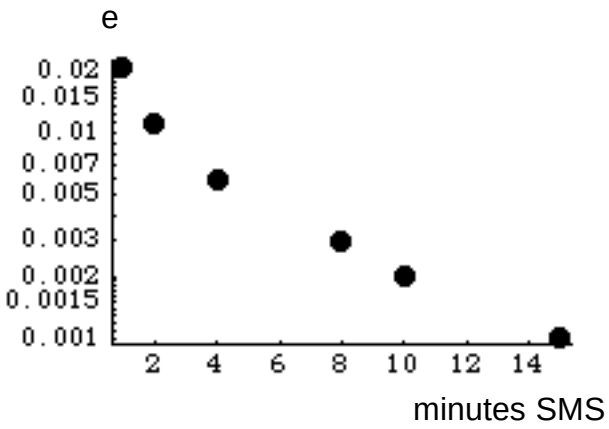
Eccentricity detection . . .

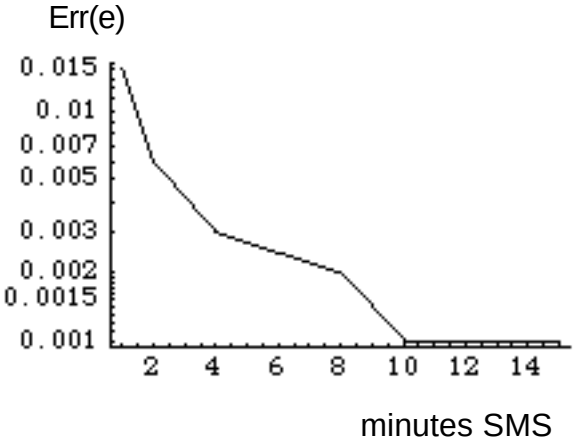
GTO





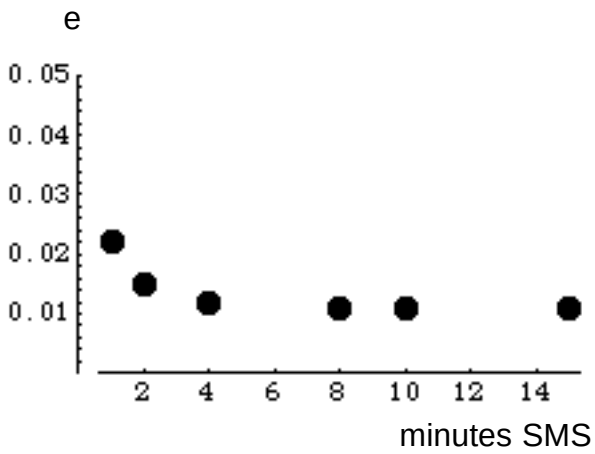
GEO

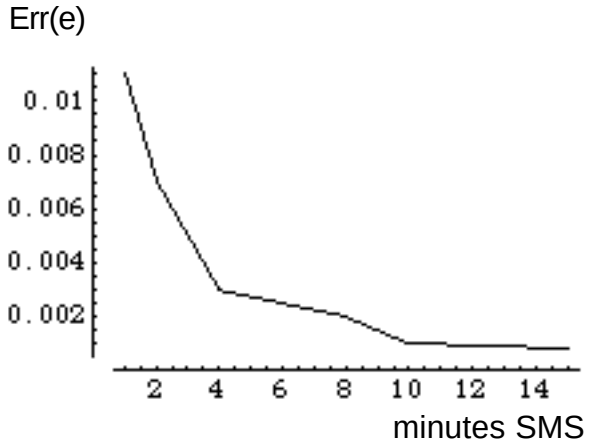




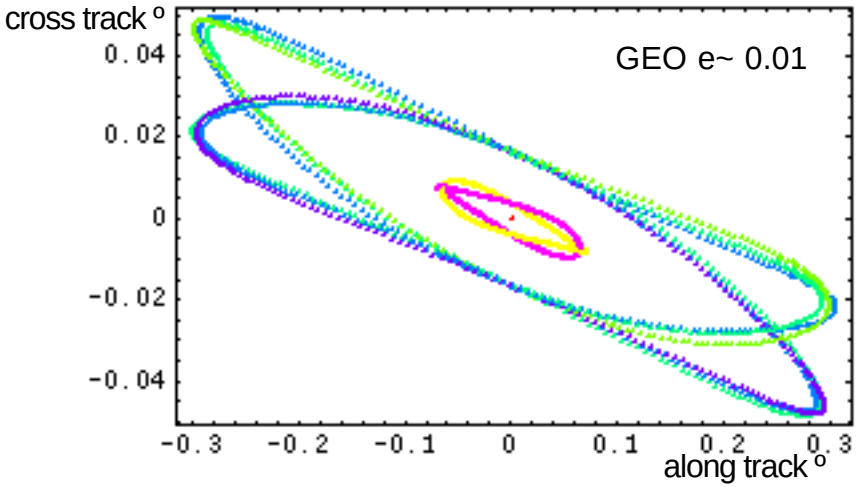
Eccentricity detection . . .continued

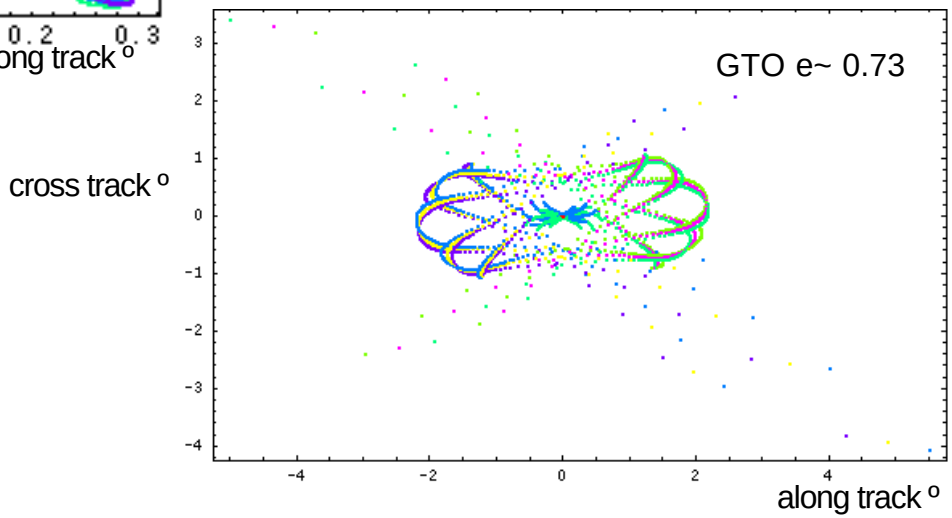
GEO debris





Modelling the re-acquisition phase . . .

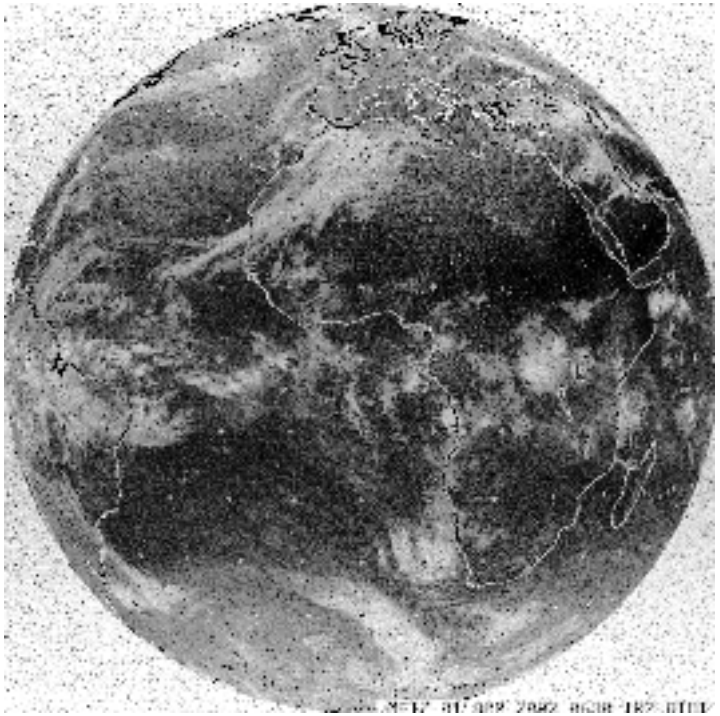




But is it feasible . . . ?

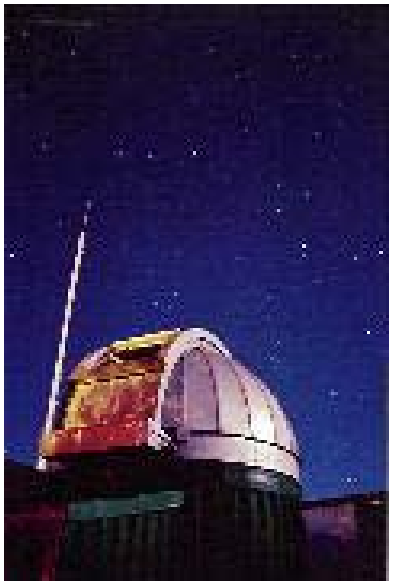
Europe has many potential co-operating sites
Common time from satellite or VLF system
Common Earth model for site position
Common communications via Internet or GSM

? Clear skies: distributed observing helps



But is it feasible . . . ?

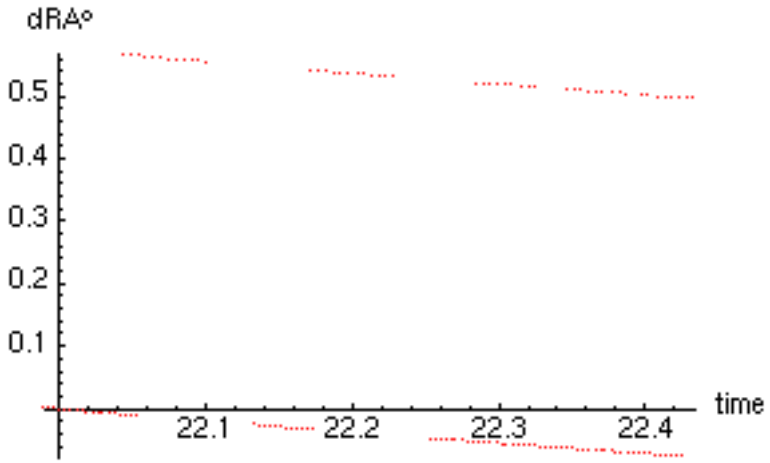
We have carried out method trials using the 1m telescope at Zimmerwald and various members of the UK MoD's PIMS network

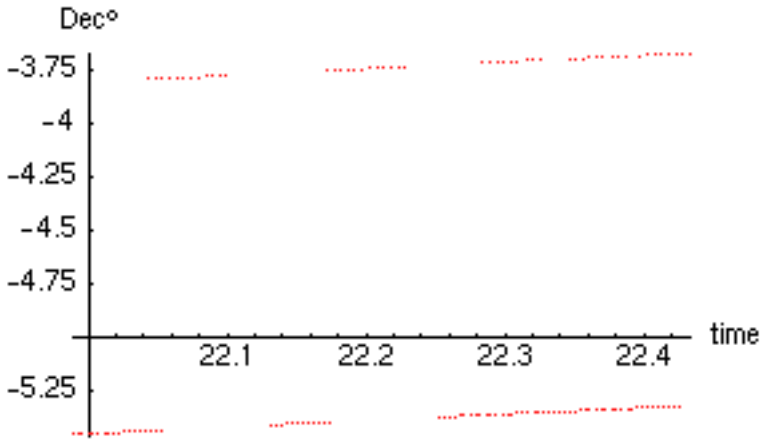


Trials – sensors used

Zimmerwald	Passive Imaging Metric System (PIMS)
alt-az “all orbits”-capable mount	alt-az GEO/GTO/MEO/HEO-capable mount
1.0 m aperture	0.4 m aperture
2k x 2k cooled scientific CCD	1k x 1k cooled scientific CCD
24 arc minute field of view	40 arc minute field of view
observer-driven	autonomous robotic system
Switzerland	Herstmonceux, Gibraltar, Cyprus
Astronomical Institute, University of Bern	UK Ministry of Defence

Trials – observations from SMS tracking





Trials – results from SMS tracking

GEO payload example (1998-035-A)

Short-arc circular orbit is better than the SMS orbit.

GEO debris example (1999-047-E)

Short-arc circular orbit: ~ 6º/day drift – so object probably not able to be re-acquired on the next night

SMS short-arc orbit: ~ 0.7º/day drift

The optics and orbits problem . . .

How to <u>avoid</u> being misled, part 2

Take l o n g -arc tracks... and compute an elliptical orbit from the angles-only observations

OR

Take multi-site angles-only observations

. . . the asynchronous multi-site method

Summary

Multi-site tracking of objects enables optical sensors to detect even quite small eccentricities in found-object orbits.

The length of track necessary appears to be quite short – only a few minutes – to provide detection of even small (~0.01) eccentricities.

A trial has been successfully carried out.

The method benefits include...

...A cleaner catalogue – because of double-detection and better orbits.

...Follow-up observing is easier and less sensor time is wasted.

Acknowledgements

Parts of this work were carried out by Observatory Sciences Ltd. under contract from the UK Ministry of Defence.

The PIMS network of deep-space optical sensors is a facility of the UK Ministry of Defence.

The authors would like to thank the observers at the Zimmerwald telescope facility of the Astronomical Institute, University of Bern